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Wildland Fire Management Economics: A State of the Art Review and Bibliography

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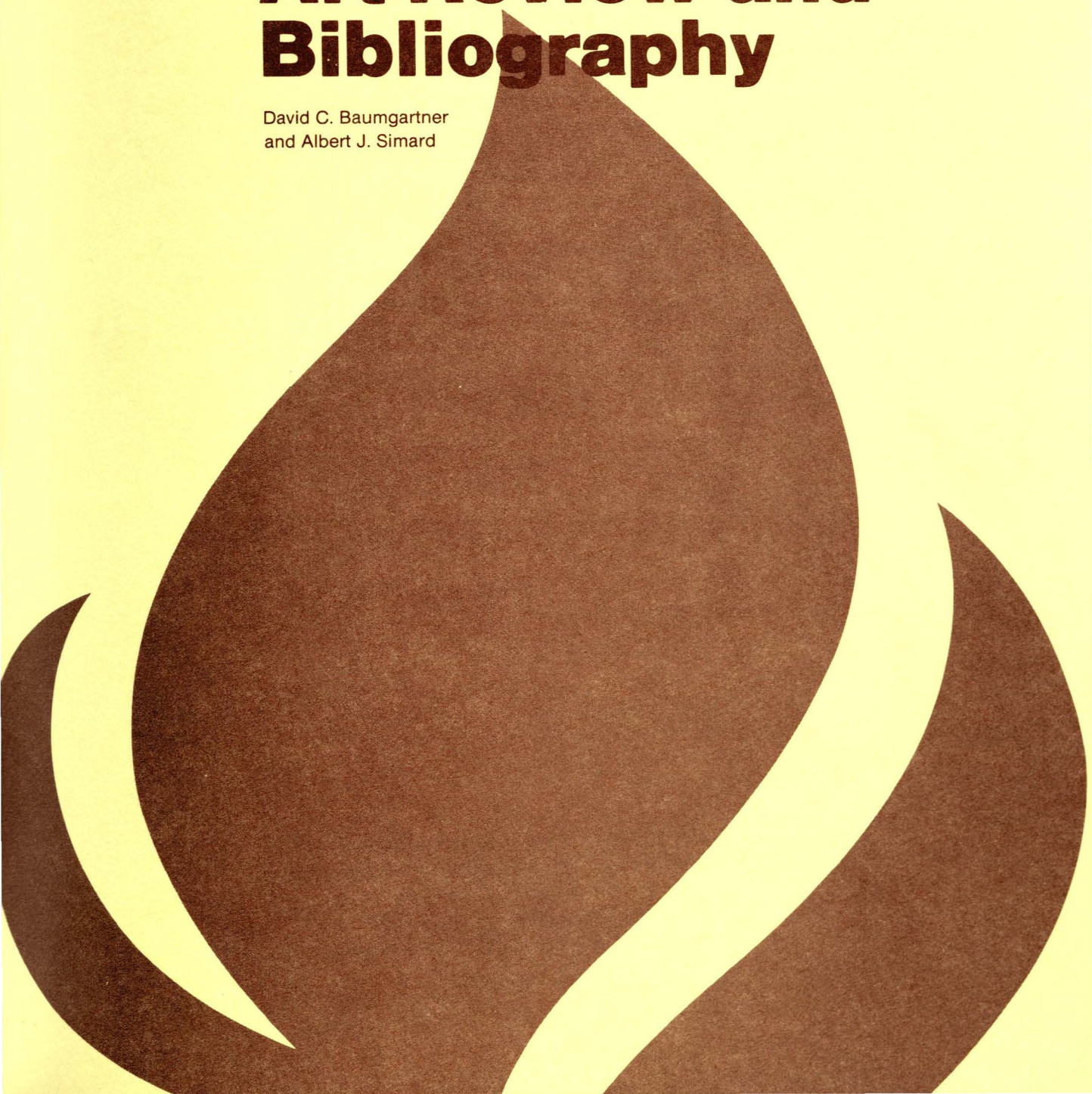

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WILDLAND FIRE MANAGEMENT ECONOMICS: A STATE OF THE ART REVIEW AND BIBLIOGRAPHY

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Past wildfire management strategies have neglected the fact that wildfire may have beneficial as well as undesirable effects and that fire management should be viewed, not in isolation, but within the context of overall land management objectives (Barney 1975, Lotan 1979). As a result, management strategies were framed with the objective of minimizing the time required to control fires, the number of fires, the size of fires, or the acreage burned. Scant attention was paid to the economic consequences of these strategies.

However, more and more fire management agencies are now being asked to justify the usefulness of their programs in terms of economic efficiency and to fully recognize the potential beneficial effects of some fires as well as the necessity to view fire management as an integral part of land management. Attempts have been made to determine: appropriate fire management budgets; proper allocation of expenditures between various fire management functions; and costs, damages, and benefits of wildland fire and fire management programs.

The objective of this review and interpretation of the literature pertaining to fire economics is to provide essential background information for selecting, developing, and applying appropriate techniques for evaluating fire management programs.

METHODS

The bibliography includes references concerned with applying economic techniques to solve wildland fire management problems. It was compiled from an extensive search of a wide variety of sources. Some citations were obtained locally, either from the USDA Forest Service North Central Forest Experiment Station Fire Management Project files or the Michigan State University library. Others were obtained from bibliographic data bases such as FIREBASE and the DIALOG service of Lockheed Information Services, which includes AGRICOLA (Bibliography of Agriculture). Generous support was obtained from USDA Forest Service and university researchers with past or current interest in wildland fire economics. Additional citations and information were obtained from key USDA Forest Service Cooperative Fire Protection, Research, and National Forest System staffs. State foresters and other Federal land management agencies were contacted by letter and asked to contribute relevant materials and we received a reply from fire management agencies from 26 States.

Even given the effort described above, the bibliography is not exhaustive. However, we feel it represents the directly relevant literature, particularly since 1960, and accurately describes the current state of the art in wildfire economics.

Annotations and key words are provided for a majority of the references. They are, however, omitted if a copy of the document or abstract could not be obtained or if the title seemed to adequately describe the content of the material. Several books that provide good general background in wildland fire management or in resource economics are listed separately at the end of the bibliography.

One or more of the following criteria were used for including references:

(1) The reference provided an example of how existing economic theory might be applied to fire management.

(2) The reference described a practical example of the use of economics in wildland fire management using real data.

(3) The reference reflected the use of economics in past or current research and/or policy direction of the USDA Forest Service or other fire management agency.

(4) The reference contained a useful bibliography of related material and/or synthesized a large volume of loosely connected information.

(5) The reference was current or its message had retained importance in essentially unchanged form.

ECONOMIC THEORY

Gorte and Gorte (1979) explore the history and evolution of economics as applied to fire management, particularly the cost-plus-loss concept. They trace the development of this concept beginning with the work of Sparhawk (1925) and Flint (1928) who were among the first to develop least-cost-plus-loss models. Next, they reviewed the work of Hornby (1936) who used acreage burned rather than presuppression expenditure as the independent variable. They then discussed the research of Headley (1943) who provided "the first attempt at a thorough analysis of fire control policy alternative."

The work of Craig *et al.* (1945) who recognized the need for marginal analysis is described as are the findings of Arnold (1949) who developed a model to derive suppression-cost-plus-damage for a number of presuppression levels measured by attack time, and Mactavish (1965) who worked with an expanded version of Arnold's model. Parks' (1964) model, which was "analogous to the first step of Arnold's model," is noted as is the work of Davis (1971) who explicitly recognized some limitations of the least-cost-plus-loss models. Finally, they describe the work of Simard (1976) who augmented the cost-plus-loss concept by equating the ratios of marginal factor costs to marginal value products among the various fire management inputs. He also explicitly recognized the possible beneficial effects of fire using the same analytical technique.

Mills (1979, 1980) also explicitly recognizes the possibility of beneficial wildfire effects noting that the "cost-plus-loss" concept would be more properly labeled "cost-plus-net value change." He also correctly points out that minimizing "cost-plus-net value change" leads to the same program selection as maximizing financial return expressed as present net worth. Similarly, the last program increment added before reaching the minimum has a benefit-cost ratio of 1.0 and an internal rate of return equal to the next best alternative rate. Gorte and Gorte (1979) describe the work of several researchers (O'Connell 1971, Zivnuska 1972, Jischke and Shamblin 1974) who have used variations of benefit-cost analysis in analyzing fire management economics. Nautiyal and Doan (1974) used an indifference approach with which a manager can trade harvested acres for burned acres and offset protection costs with timber sale receipts.

All in all, the economic theory of fire management is compatible with basic applied production, or microeconomic theory, and is well accepted. Some models needed to determine the economic efficiency of some components of fire management programs are available and others are being developed. The "cost" component needed as input for the models is reasonably easy to obtain with good bookkeeping. The basic difficulty lies in determining and predicting losses and benefits, or the net value changes wildfires have caused or are likely to cause. These crucial elements for any of the economic models cited above are virtually impossible to determine precisely. Even for timber, the questions of what the appropriate discount rate should be for future market values or what the future value will be, are unresolved. Nonmarket values and off-site values are even more difficult to determine precisely.

VALUE-AT-RISK AND APPRAISAL OF NET VALUE CHANGE

It has been recognized that past fire damage appraisal systems have not been adequate to serve the needs of the basic theoretical economic fire management models. Economic studies to determine an "adequate level" of fire protection or "justifiable expenditures" were undertaken by Davis (1965), Vogenberger *et al.* (1957), Miller (1968) and Arnold (1949). All emphasized the difficulty inherent in measuring the value changes caused by fires and prefire values that could be affected by fire. All finally resorted to limiting their analysis to a few of the more measurable market values or to including subjective approximations for some values to at least show how their models might work. Noste and Davis (1975) demonstrated the inconsistencies in appraisal techniques by comparing appraisals by the USDA Forest Service and the Bureau of Land Management following two large fires.

Wildfire value change appraisal has been receiving increasing attention. Crosby (1977) developed a general guide for appraising wildfire damages, benefits, and resource values protected. Marty (1979) developed an

economic valuation system for fire management planning on the National Forests. Gorte (1979) is completing a new system that permits more accurate appraisal of wildland fire damage in Wisconsin. This system recognizes that some fire effects are beneficial and carefully considers nontimber values. Lewis *et al.* (1979) are studying the "values-at-risk" from wildfire in Alabama.

APPLICATION

Although the solution of prefire value and postfire value change problems is incomplete, several recent studies have attempted to apply the best information available in benefit-cost or cost-plus-loss economic models. Winkworth *et al.* (1979) are conducting a benefit-cost analysis of progress in forest fire protection in North Carolina while Carmichael *et al.* (1979) have completed a benefit-cost study in California. Schweitzer *et al.* (1980) evaluated four levels of initial action and aviation program input using the FOCUS simulation model (Flatman and Storey 1979).

Researchers and policy directors in the USDA Forest Service have recognized the need for better economic information on fire management program alternatives. A policy analysis staff report (Gale 1977) included the following recommendations:

I. Develop new fire management policies that provide a broader, more positive approach to fire.

II. Establish procedures for determining reliable esitmates of forest values.

III. Develop an integrated fire management planning process.

IV. Improve the accounting and budgeting systems of fire management.

V. Develop and implement a comprehensive evaluation system.

Item I. was largely accomplished in February 1978 when a revised fire management policy became effective stating: the basic fire management policy on National Forest System land is to provide well planned and executed fire protection and fire use programs that are cost-effective, responsive to land and resource management goals and objectives, and supportive of the 1974 Forest and Rangeland Renewable Resources Planning Act resource outputs. Efforts to accomplish recommendations II., III., and V. are reflected in the work of Schweitzer *et al.* (1980) entitled "A partial efficiency analysis of the fire management program on six National Forests." This work will be discussed in greater detail because it represents very well the state of the art in evaluating the economic efficiency of USDA Forest Service fire management programs.

Schweitzer *et al.* (1980) evaluated the economic efficiency of the initial attack and aviation component of the fire management program on six widely spaced National Forests using a marginal analysis format. Minimizing the program cost plus the net change in the value of response outputs and structures was the economic efficiency criterion. Four program levels were evaluated. The results of this study included the following:

(1) "The lowest program tested was the most efficient in the majority of the simulated fire years, 12 out of 17 years."

(2) "The most efficient initial attack and aviation program level was not affected by the severity of the fire year in four of the six case study forests."

(3) "The simulated fire suppression cost drops in response to increases in the initial attack and aviation program levels in all case studies."

(4) "The net value change of resource outputs and structures caused by fires was a very small percentage of the total cost + net value change in 13 of the 17 years studied."

(5) "The vast majority of the net value change in these cases was the loss of commercial timber and structures."

The authors also document the limitations of this study that must be overcome before a complete economic analysis of alternative fire management programs can be conducted. Included are:

(1) "Effectiveness estimates of program alternatives and mixes for all five major components of the fire management program (prevention, detection, initial attack, escaped fire suppression, and fuel treatments) must be incorporated within a single model construct."

(2) "The range of the program levels tested should be wider than the 1979 −20 percent to 1979 + 40 percent tested in this study to ensure that the minimum cost + net value change is located."

(3) "The stochastic element must be more completely incorporated throughout the entire analysis from its source in fire occurrence and fire weather variations through to a probability

distribution of resource impacts and cost + net value change itself."

(4) "Even though the preliminary sensitivity analysis in this study demonstrated that errors in the fire effects and resource value estimates would not materially affect the answers on economic efficiency, the accuracy of some of these estimates is still quite suspect."

This study demonstrates that economic efficiency analysis for wildland fire management can be practically applied. At the present time it can indicate general management guidelines using the best resource value figures and prediction techniques available. As these improve, more specific guidelines can be developed. The sensitivity analysis provides important clues as to which resource value and value change variables are most crucial in their influence on the analysis. Research is currently underway (e.g., Althaus 1980, Mills 1980, Simard *et al.* (1980) that should improve resource value, value change, and value-at-risk information including nonmarket, secondary, and off-site values.

The few economic studies of State fire management programs have indicated that past and current fire protection programs have been cost effective and that additional investments in these programs are justified. For example, Winkworth *et al.* (1979) concluded "with every passing year, the timber values at risk in North Carolina are growing, not only due to the success of public incentive programs but as a result of real price increases for standing timber. Using economic guidelines,greater expenditures for fire protection are justified (moreover they are essential) when values at risk increase . . . . North Carolina has not yet reached the point of diminishing returns in wildfire protection." The preceding results are in contrast to those obtained for National Forests, which often indicated that the lowest fire protection level examined was the most cost effective. The contrasting results are not necessarily inconsistent because the fire management programs examined for the National Forests are much more intensive and thus more likely to have reached a point of diminishing returns.

EQUITY

The state of the art in applying economic principles to wildfire management programs appears to be sufficiently developed to provide general guidelines and evaluations. Current research holds the promise of improving the state of knowledge and providing more specific results. Unfortunately, however, this is true only for evaluating economic efficiency. Further, much of the efficiency analysis has focused on the needs of Federal land managers, particularly the USDA Forest Service, in western States containing large acreages of National Forests. In this case it seems reasonable that the costs and benefits of public wildland fire management should be examined from a societal viewpoint because public land management plans and objectives are clearly intended to serve the public interest.

The use of economic analysis to examine the equity of wildfire management programs either separately or in combination with efficiency analysis has been limited. The question of equity is much more important when developing an economic rationale to evaluate programs for managing wildfire on State and private land. To indicate the costs and benefits associated with wildland fire management and assume that they accrue to some vaguely defined unit called "society" is insufficient. Equity analysis is necessary to determine who pays (or should pay) the costs or who reaps the benefits of wildfire management programs. Specific questions that must be addressed were posed in a State and Private Forestry status report on Cooperative Fire Protection Economic Analysis at a USDA Forest Service Regional Foresters and Directors meeting in Missoula in July 1980. They are:

(1) "What level of fire protection and cost is most appropriate and commensurate with management objectives and investments for land protected by States?"

(2) "For lands protected by States, who has interest and derives benefits from fire protection efforts and costs?"

(3) "What protection level and cost is required to protect national interest in the lands protected by States?"

(4) "Who should pay the cost of fire protection and why?"

Harden (1980) addressed the first question. He attempted to measure the cost effectiveness of potential increases and decreases in a State fire protection budget using information developed in the National Forest System's Fiscal Year 1980 Budget Analysis for the Mark Twain National Forest in Missouri. He extrapolated this information to State and private land in Missouri and obtained additional data from the Missouri Department of Conservation to estimate the cost effectiveness. He concluded that reducing suppression expenditures could result in large increases in timber damage and that increasing such expenditures would be cost effective in eastern Mis-

souri and marginally cost effective in western Missouri. This approach gives a partial answer to question (1) but it is still primarily concerned with economic efficiency rather than equity. Questions (2), (3), and (4) involve equity and remain largely unanswered.

Only a few studies have dealt with the question of equity in fire management programs in conjunction with economic efficiency. Kling (1951) and Swager *et al.* (1958) analyzed the cooperative forest fire program. Kling was primarily concerned with a nonquantitative description and evaluation of policy and administrative programs. Swager *et al.* attempted to determine appropriate funding levels for adequate fire protection on non-Federal forest land and how the costs should be shared by Federal, State, and private parties. Although this research provides a gross estimate of equity for sharing costs between Federal and State governments and private sources, it does not indicate how Federal funds should be distributed among States or how States should distribute costs and benefits internally.

We did not locate any references since the work of Swager *et al.* (1958) that dealt explicitly with the question of equity in wildland fire management programs. Although we could have missed some, a decided gap in the state of the art of fire economics is clearly indicated. This is surprising, because questions of equity would appear to be addressable. Relevant data should be available, although somewhat tedious to collect, and conventional welfare economics and public finance theory should be applicable.

SUMMARY

In terms of economic efficiency, the state of the art for using economics in wildland fire management has made significant advances. Partial economic efficiency models have been developed, are being applied, and are capable of providing general guidelines for some aspects of public wildland and fire management. Further advances are likely, such as the development of more complete economic models as well as improved resource value, value change, and value-at-risk information. Recent work by Schweitzer *et al.* (1980) and its expansion in the 1980 Budget Analysis (U.S. Department of Agriculture, Forest Service 1979b) for the National Forests is representative of the current state of the art. Harden (1980) has shown that there are cases in which specific National Forest analyses can be extrapolated to nearby State land, at least in terms of area-wide economic efficiency.

Several problems remain, however, even for economic efficiency analysis. A gap will always exist between what is theoretically desirable and what is practical to apply, given the limitations of time available for management decisions and the cost of information needed for available models. The models are compromises between what should and what can be done. A similar situation exists for values, value changes, and values-at-risk. Theoretically, these should all be measured and expressed in monetary terms but this may not be practical. For example, much controversy occurs as to how losses should be appraised even for timber, one of the most marketable resources. Selecting the proper method to use for measuring nonmarket values is even more difficult and will always be somewhat subjective and arbitrary. At the far extreme of measurement and monetary expression difficulty are noneconomic resource values, such as endangered species habitat. The noneconomic value must be recognized and considered, however, in determining fire management policy and practice. The potential for rare but large and disastrous conflagrations must also be considered even though conventional economic efficiency analyses are poorly suited to incorporate such events.

In contrast to the well developed state of the art for economic efficiency, the issue of economic equity has received little attention. Serious attention should be devoted to the question of who pays, or should pay, the costs and who obtains the benefits of wildfire management programs. With such information, more complete economic efficiency models, and improved resource value data, it should be possible to provide improved and more specific guidelines for fire management, which will result in economically efficient and equitable programs.

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